Electrical Conductivity

Electrical conductivity measures the ease with which an electric current can pass through a medium. It is the reciprocal of the resistivity. Alternatively, it is the quantity of electric charge transferred across a unit area, per unit potential gradient (voltage), per unit time.

Values were obtained by mathematical conversion of the resistivities reported in the 15th edition of LANGE'S HANDBOOK OF CHEMISTRY, J.A. Dean, Ed., McGraw-Hill, 1999. Data from LANGE'S HANDBOOK OF CHEMISTRY was collected online at:

http://www.knovel.com/knovel2/Toc.jsp?SpaceID=10093&BookID=47 (accessed July, 2002)

For some elements, such as carbon in the form of graphite, electrical conductivity is anisotropic--it differs when measured in different directions. The electrical conductance of graphite is 3.7/(mohm-cm) in the plane of the hexagonal layers of carbon atoms, but is 0.0017/(mohm-cm) perpendicular to those layers. This can complicate measurements of electrical conductivity (see THERMAL CONDUCTIVITY). The above sources do not mention this problem, and report electrical resistivities as a single value for each element.

Conduction

The Physics Hypertextbook™

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Discussion

Heat conduction (as opposed to electrical conduction) is the flow of internal energy from a temperature to one of lower temperature by the interaction of the adjacent particles (atoms, electrons, etc.) in the intervening space.

Factors affecting the rate of heat transfer by conduction.

1. temperature difference
2. length
3. cross-sectional area
4. material

$$P = \frac{\Delta Q}{\Delta t} = \frac{kA\Delta T}{\ell}$$

Fourier's law (compare to Ohm's law)

$$\mathbf{\Phi} = \frac{P}{A} = \frac{\Delta Q}{A\,\Delta t} = -\,k\,\nabla T$$

Note: it's the rate at which heat is transferred, not the amount of heat transferred.

Conductivities vary for material being greatest for metallic solids, lower for nonmetallic solids, very l extremely low for gases. The best ordinary metallic conductors are (in decreasing order) silv aluminum, beryllium, and tungsten. Diamond beats them all, and graphite beats diamond only i forced to conduct in a direction parallel to the crystal layers. The material with the greatest therma superfluid form of liquid helium called helium II, which only exists at temperatures below 2.17 K. unlikely you will encounter this substance, it is really not worth thinking about except in the exceptional material.

Thermal Conductivity for Selected Materials (~300 K except where otherwise indicat

material	k (W/m·K)	material	k (W/m·K

air, sea level	0.025	neoprene	0.15 - 0.4
air, 10,000 m	0.020	nickel	90.7
aluminum	237	particle board	0.15
asbestos	0.05 - 0.15	paper	0.04 - 0.0
asphalt	0.15 - 0.52	plaster	0.15 - 0.2
brass (273 K)	120	platinum	71.6
brick	0.18	plutonium	6.74
bronze (273 K)	110	plywood	0.11
carbon, diamond	895	polyester	0.05
carbon, graphite (‖)	1950	polystyrene foam	0.03 - 0.0
carbon, graphite (⊥)	5.7	polyurethane foam	0.02 - 0.0
carpet	0.03 - 0.08	sand	0.27
chromium	93.7	silica aerogel	0.026
concrete	0.05 - 1.50	silver	429
copper	401	soap powder	0.11
cotton	0.04	snow (< 273 K)	0.16
feathers	0.034	steel, plain (273 K)	45 - 65
fiberglas	0.035	steel, stainless (273 K)	14
freon 12, liquid	0.0743	straw	0.05
freon 12, vapor	0.00958	teflon	0.25
felt	0.06	tin	66.6
glass	1.1 - 1.2	titanium	21.9
gold	317	tungsten	174
granite	2.2	uranium	27.6
helium gas	0.152	vacuum	0
helium I (< 4.2 K)	0.0307	water, ice (223 K)	2.8
helium II (< 2.2 K)	~100,000?	water, ice (273 K)	2.2
ice cream powder	0.05	water, liquid (273 K)	0.561
iron	80.2	water, liquid (373 K)	0.679
lead	35.3	water, vapor (273 K)	0.016
limestone	1	water, vapor (373 K)	0.025
marble	1.75	wood	0.09 - 0.1
mercury	8.34	wool	0.03 - 0.0
mica	0.26	zinc	116
mylar	0.0001?	zirconia	0.056?

Thoughts on conductivity ...

- The preferred utensil for candy making is the wooden spoon. Metal utensils conduct heat ε with controlled crystallization.
- Why are toilet seats cold even if the air in the bathroom isn't?
- Why can you hold your hands in a blasting hot oven for the few seconds it takes to remo feeling any ill effects, but if you touch the roasting pan for even a split second you'll wind up
- Why did Eskimos traditionally build shelters out of snow? Isn't snow cold?

Related quantities: r value.

$$\Delta T = R\frac{\Delta q}{\Delta t} \quad \Rightarrow \quad R = \frac{\ell}{kA}$$

The clo. studies of clothing have lead to the definition of the unit of clothing, which corresponds to tł of clothing needed to maintain a subject in comfort sitting at rest in a room at 21 °C (70 °F) witŀ 0.1 m/s and humidity less than 50%. One clo of insulation is equivalent to a lightweight business sui

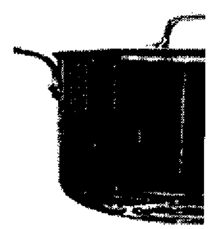
Newton's law of cooling $Q/t \propto \Delta T$. Heat leaks faster from a cool house than a warm house. Th effective to turn your air conditioner off when you're away, than to leave it on hoping to keep your hc

Summary

- bullet

Problems

practice

1. 

   The cook pot shown in the photograph to the right is quite unique. Pots of this sort are usu by stamping a single sheet of heavy gauge stainless steel or aluminum in a powerful metal different in that it was stamped from a "sandwich" of steel-copper-steel (note the copper stainless steel bottom and sides). What advantage would such a complicated pot have c metal pots when used in the kitchen? Why have a copper core? Why use stainless steel bottom? What's the deal with this pot?

   Solution ...

   Copper is one of the best conductors of heat available (only silver has a higher thermal c stainless steel is a relatively mediocre conductor (mercury is one of the few metals witł conductivity). Using copper in the base would increase the rate at which heat was transferre or heating element to the food, while using stainless steel on the sides would reduce the ı was lost from the food to the environment. Such an arrangement results in an effective cook

rapidly to changes in burner output. Capping the copper base with stainless steel seems tc efficiency, however.

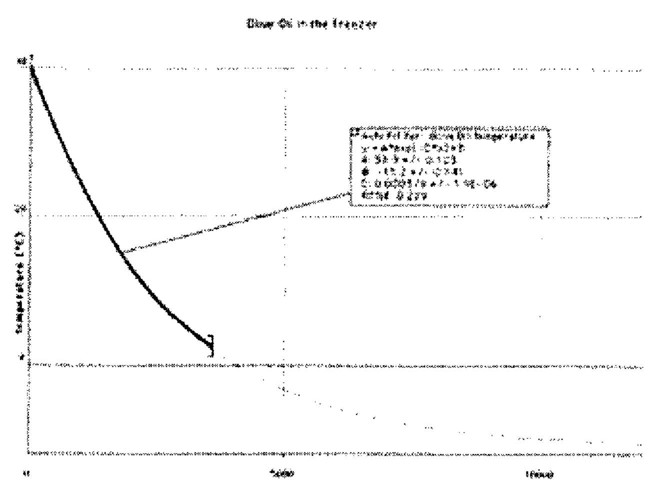
For many applications a base that was made only of copper would probably be too effect heat. Heat applied to a small region would be transferred so rapidly that it wouldn't have tim the pot's bottom. This would result in uneven cooking and possibly even local areas of scorc base with stainless steel slows the immediate rate of heat transfer from the burner or he once this heat enters the copper core its high conductivity would spread the heat rapidly parts of the base.

There are also some esthetic issues behind this design. Copper is notoriously hard to cle steel is, well, stainless. Cooks who insisted that their cookware sparkle at all times (even or are never in contact with food) would probably appreciate the use of low maintenance ma the exterior. The thin, exposed band of copper near the bottom is no doubt there to wandering customers.

2. Write something else.
   - Answer it.
3. olive-oil.txt
   A liter of warm olive oil was placed in a freezer and allowed to solidify. Temperature me taken every six seconds for one hour (3600 s). Determine its final equilibrium temperature.

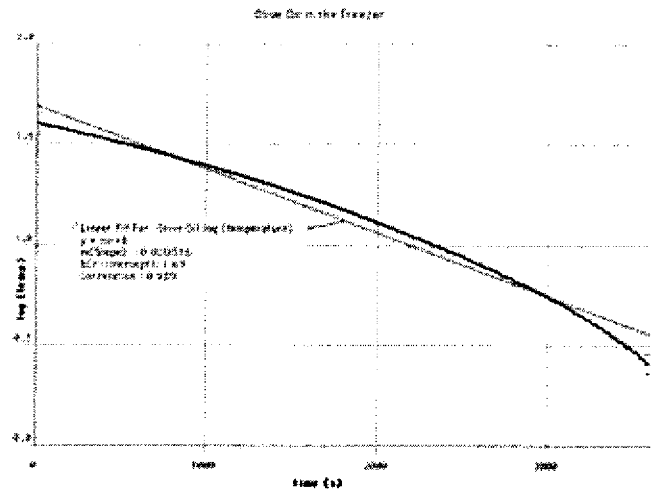
   Solution ...

   The temperature data appear to follow an exponential decay function. An automatic curve value of −11.2 °C. The fit looks good early on, but near the end of the data collection noticeable deviation, which leads me to believe that the extrapolation to the limiting ec unreliable.



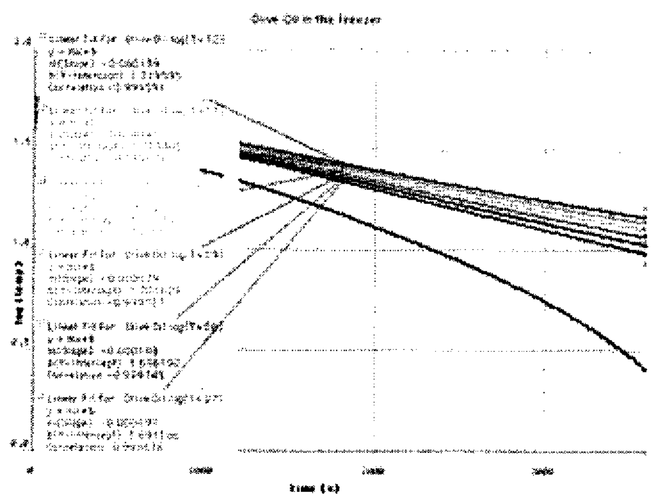
[magnify]

Taking the logarithm of a quantity that varies exponentially will transform it into a linear graph of log(temperature) vs. time does not fit a straight line, however, and is not technicall data needs to be massaged a bit to get it to fit.


[magnify]

Recall that the limit of an exponential decay process is zero. But the olive oil in our freezer up below the freezing point of water (that is, below zero celsius). In order to get our tei approach zero we will add a constant number to every value. The constant that results in the give the final temperature of the oil.

Taking the logarithm of a quantity that varies exponentially will transform it into a linear graph of log(temperature) vs. time does not fit a straight line, however, and is thus not strictly data needs to be massaged a bit to get it to fit.


[magnify]

Of all the adjustments tried, the graph of log(T+09) best fits a straight line. Assuming the co an exponential decay function, the final temperature of olive oil in the freezer is −9 °C. I co reliable answer than −11.2 °C.

4. Calculus problem. Show that Newton's law of cooling produces a temperature cu exponentially.
    - Answer it.

numerical

1. Some sort of blubber problem would be nice

The ultrasound scans shoed a relatively uniform layer of blubber running virtually length of the body, ranging from 1.6 to 2.4 inches thick, in adults that weigh betwee 1,100 pounds. Even in one-month-old pups, which are the size of mature Saint Be blubber is between 1.2 and 1.6 inches thick. (Sunbathing Seals of the Antarctic. Williams. *Natural History*. October 2003.)

Resources

- general
  - National Institute of Standards and Technology (NIST)
    - Heat Transmission Properties of Insulating and Building Materials, Standar Program
    - Thermal Conductivity, Building and Fire Research Laboratory

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